A New Era and a New Tradespace: Evaluating Earth Entry Vehicles Concepts for a Potential 2026 Mars Sample Return

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International Planetary Probe Workshop 2018
June 11th – 15th 2018

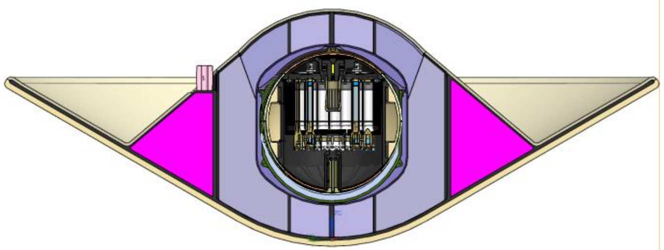
Introduction

This year NASA kicked off a new multi-center Earth Entry Vehicle (EEV) formulation team to mature EEV concepts and prepare for a potential 2026 Mars Sample Return (MSR) mission.

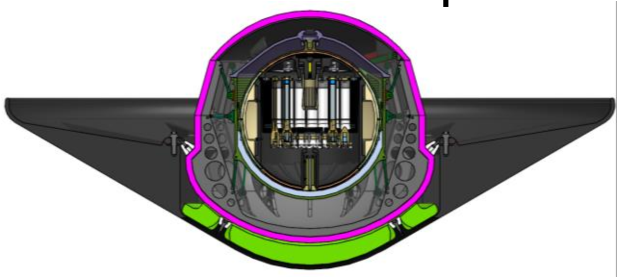
- Team is run out of the Mars Exploration Directorate at JPL with strong support from both Langley and Ames research centers.

- Team works together in many areas:
  - Concept development & maturation
  - Mission architecture and systems engineering
  - Engineering analysis & testing
  - Risk mitigation and hardware certification planning
  - NASA-ESA joint MSR studies
  - Identification & closure of critical technology gaps
  - Planning & budgeting for potential flight implementation

PICA EEV Concept



C/C EEV Concept



Ames Research Center

Jet Propulsion Laboratory
California Institute of Technology

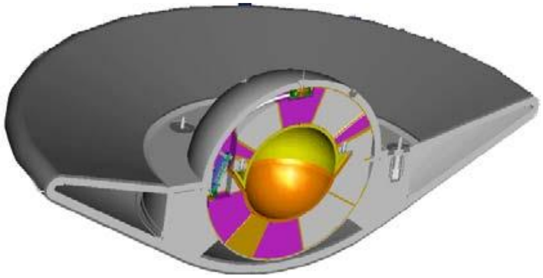
Langley Research Center

What is an Earth Entry Vehicle?

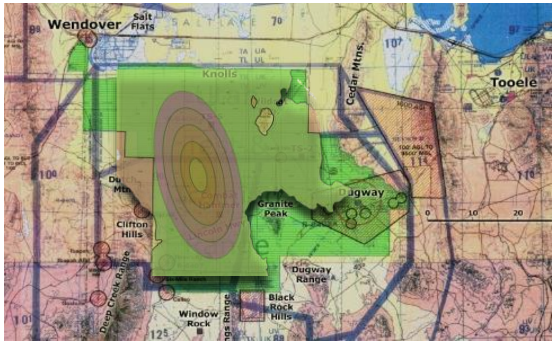
The EEV is a simple ballistic entry vehicle concept designed for sample return missions with a design emphasis on robust performance and certifiability.

1. Originally developed for a 03’-05’ MSR mission
2. Emphasis on passive design solutions: minimal/no complex active mechanisms or electronics.
3. Passively stable aerodynamics from hypersonic thru terminal velocity
4. Likely no parachute or retrorockets
5. Possibly redundant thermal protection systems
6. Samples protected by multiple layers of energy absorbers for impact landing and thermal isolation
7. Redundant sealed containers around OS/samples for planetary protection assurance aka ‘robust containment’
8. 5σ landing ellipse within a controlled landing site, (notionally UTTR)

Early NASA MSR-EEV Concept



A Predicted Landing Ellipse (Notionally UTTR)



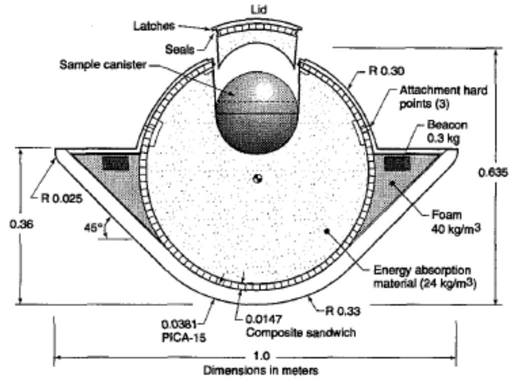
Brief History of Past NASA MSR-EEVs

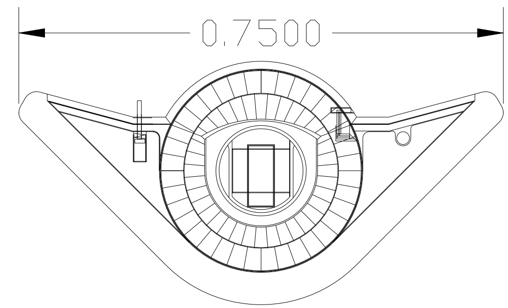
Earlier Concepts

- Early proposal concepts, small, light, notional
- Limited analysis, never built
- TPS: Phenolic Impregnated Carbon Ablator (PICA)
- Sphere-cone 45˚ w/ 33 cm tip radius

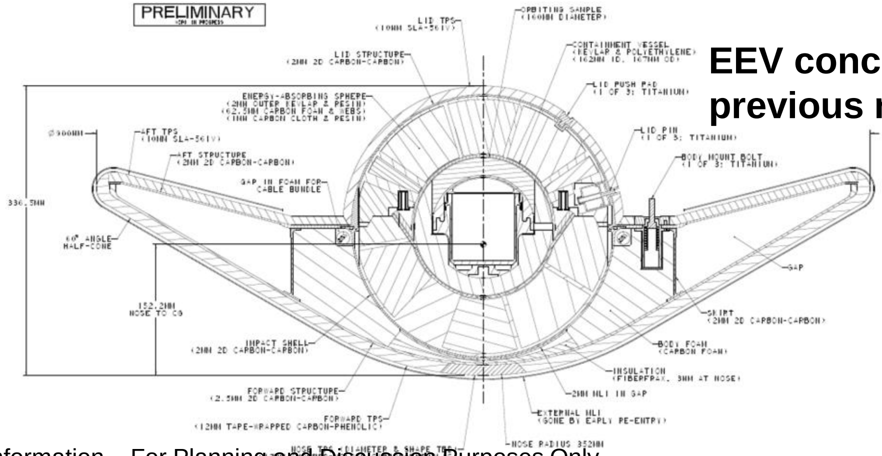
03’-05’ MSR Campaign Design

- Significant structural, aero, impact analysis, & vehicle testing
- Primary TPS: Carbon-Phenolic (CP)
- Backshell TPS: SLA-561V
- Sphere-cone 60˚ w/ 30 cm tip radius
- 44 kg Total mass, 5 kg/16 cm Orbiting Sample (OS) payload
- Planned entry velocity: 11.56 km/s at -15˚



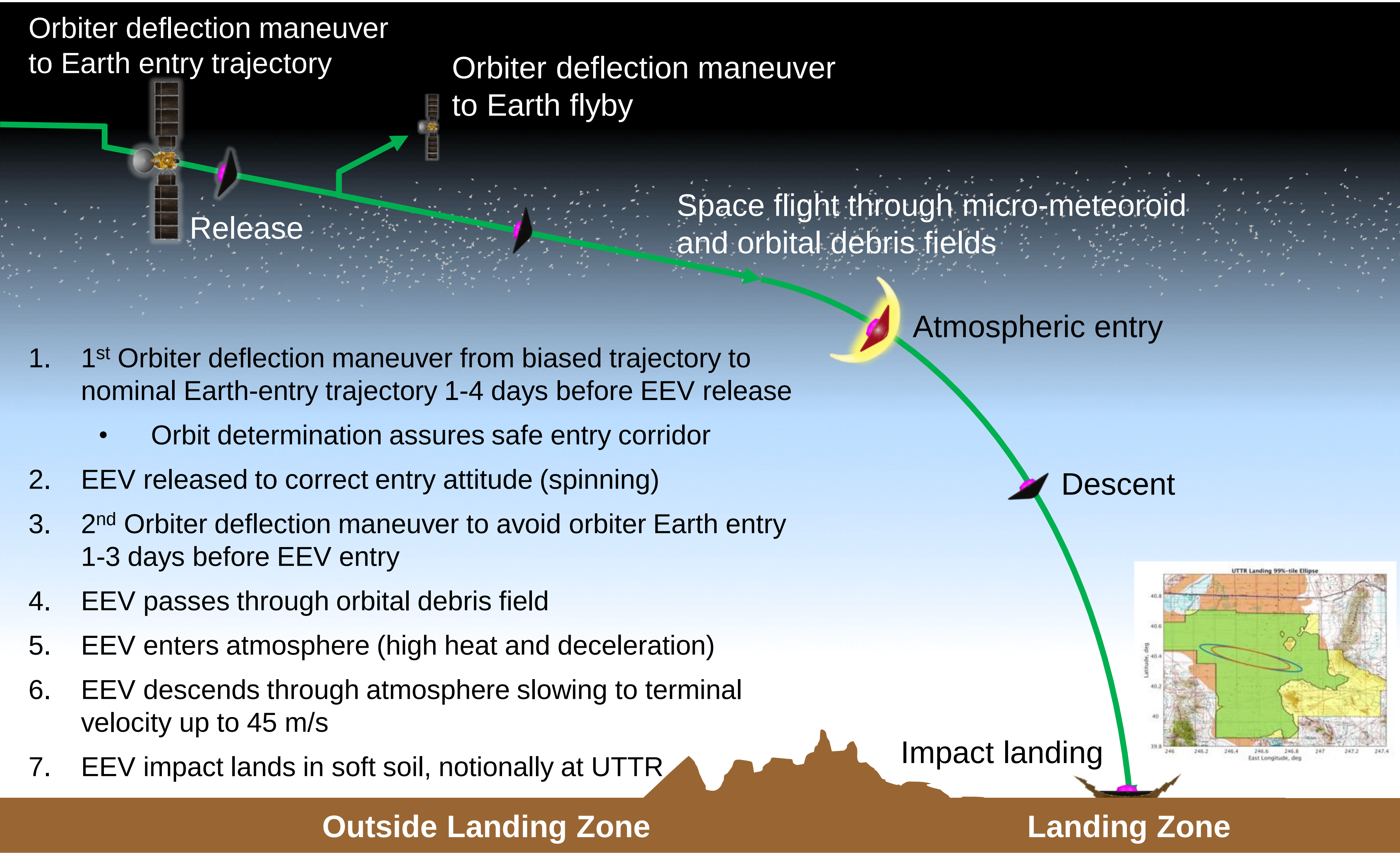


Early EEV drop test at UTTR



EEV concept at previous mission PDR

Nominal EEV ConOps



1. 1st Orbiter deflection maneuver from biased trajectory to nominal Earth-entry trajectory 1-4 days before EEV release
   - Orbit determination assures safe entry corridor
2. EEV released to correct entry attitude (spinning)
3. 2nd Orbiter deflection maneuver to avoid orbiter Earth entry 1-3 days before EEV entry
4. EEV passes through orbital debris field
5. EEV enters atmosphere (high heat and deceleration)
6. EEV descends through atmosphere slowing to terminal velocity up to 45 m/s
7. EEV impact lands in soft soil, notionally at UTTR

New Considerations for a Potential 26’-29’ MSR EEV

Mature Tubes
- Mars 2020 sample tube design finalized.
- Seal load limits require OS orientation for landing.
- Major dimensions: Length: 144 mm, Diameter: 23 mm
- Mass ~100 g depending on enclosed sample.

Maturing OS
- Reference OS concept: NTE 12.0 kg & 28 cm diameter
- Prototypes tested in robotic & impact environments.
- Other OS concepts still under consideration and trade

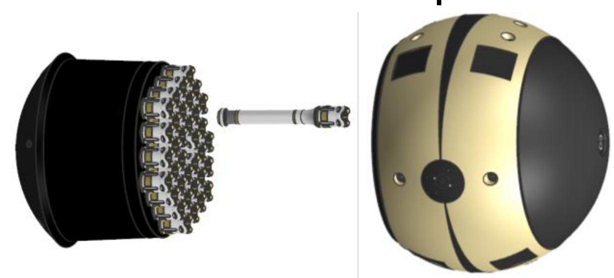
BTC & Containment Vessels
- Contained-OS mass allocation = 33 kg.
- New concepts and testing of BTC & brazing are underway.
- Leading BTC approach utilizes brazing of titanium shells positioned on the orbiter.

High Speed Entry
- Orbiter studies indicate that for a ‘one opportunity’ 2029 Earth arrival, up to 13.5 km/s atmospheric relative EEV entry velocity may be required.

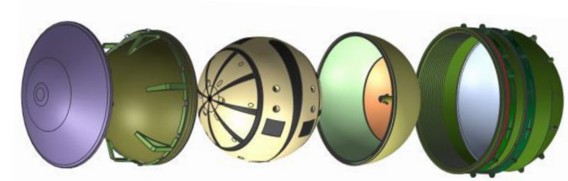
Orbiter Mass Limitations
- Due to launch vehicle constraints and high-speed return goal, EEV entry mass allocation is only 100 kg.

Post-CDR Mars 2020 Tube Design

Reference OS Concept



Redundant Containment Concept and Test Articles



EEV Concept Study

Many design options for EEV TPS, structure, shape, energy absorbers, etc. were evaluated. So far the team has down-selected to two concept families: 1) 'Cold Structure' and 2) 'Hot Structure'

2018 Study Objectives

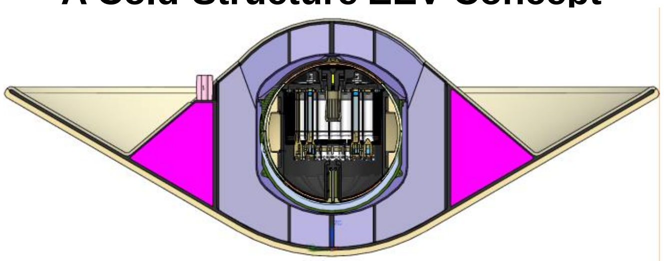
1. Demonstrate that feasible EEV design solutions can be developed that meet key vehicle requirements, fit within the MSR architecture, and are programmatically realistic.
2. Down-select to two EEV concepts to carry forward into the FY'19 design maturation and testing.
3. Formulate FY'19 and FY'20 EEV risk reduction, technology development, and conceptual design work necessary to accomplish a successful Orbiter Mission Concept Review (MCR) in early 2020.

Key Capabilities for Preliminary EEV Concepts

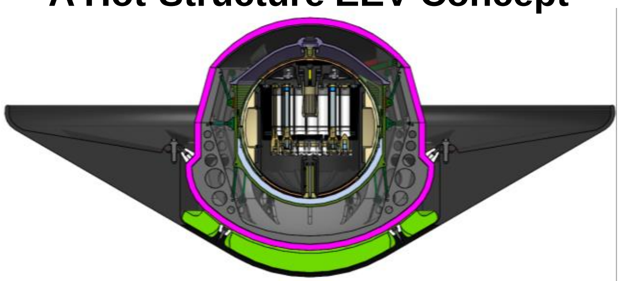
- Compatible with robotic in-space final assembly via the 'Capture Orbiting Sample Transfer And Return' (COSTAR) Orbiter payload
- Holds up to a 33 kg C-OS payload
- Total entry mass < 100 kg (including MGA and system margin)
- Earth retrograde entry at up to 13.5 km/s (atmospheric relative)
- Passively aerodynamically stable thru all flight regimes
- Peak soft-soil landing accelerations less than 1300 G at OS.
- Load limiting in case of inadvertent landing on hard and sharp surfaces for containment assurance.

All designs focus on robust performance and certifiability.

A Cold-Structure EEV Concept



A Hot-Structure EEV Concept



Current EEV Concepts

Design and analysis is on-going in many areas to mature two concepts for a November 2018 concept peer review.

Cold-Structure Concept

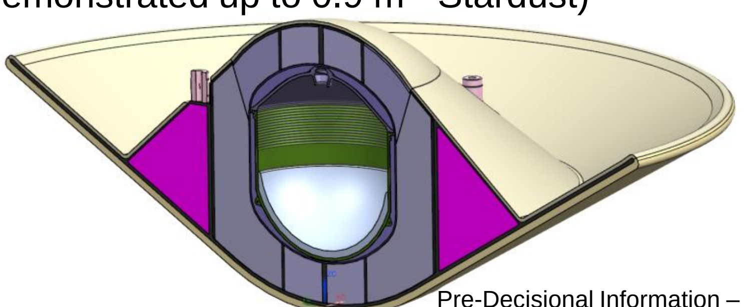
- Goal to use PICA for cost and heritage reasons.
- HEEET TPS is a promising but heaver alternative.
- Carbon-fiber ‘cold’ primary structure.
- Entry trajectory trades & TPS sizing emphasize minimizing heat flux and entry loads
- Structural and impact analysis in-progress.

Key Benefits

- Potentially lightest and least expensive option.
- Design, materials, & manufacturing techniques well understood by NASA experts.

Key Risks

- Single-string TPS may be found insufficient for MSR’s ultra-low risk posture and MM-OD threat
- High entry speeds may push PICA beyond its capability.
- Desired monolithic TPS up to 1.5 m, (PICA demonstrated up to 0.9 m - Stardust)



Hot-Structure Concept

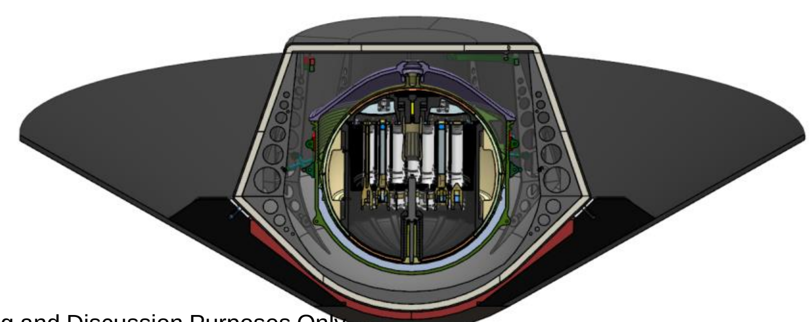
- Carbon-carbon (C/C) aeroshell doubles as TPS and ‘hot’ primary structure
- Hot aeroshell structure attaches to a ’cold’ capsule with its own secondary TPS.

Key Benefits

- C/C + secondary TPS potentially provides lower risk from MM-OD threat and high entry speeds.
- Entry trades not as limited by TPS capability.
- Mature material developed by DoD with multiple flight examples and manufactures.

Key Risks

- NASA expert experience with C/C is limited.
- Hot-to-cold structural interface design.
- Thermo-structural stresses during reentry
- Multi-piece construction may require extra certification testing & effort

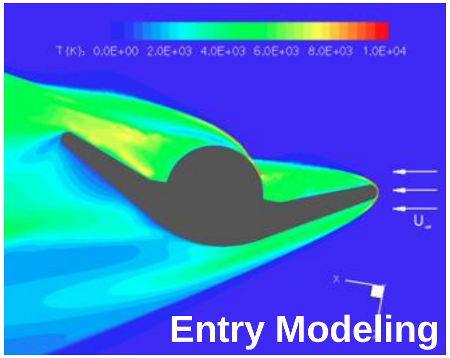


Pre-Decisional Information – For Planning and Discussion Purposes Only

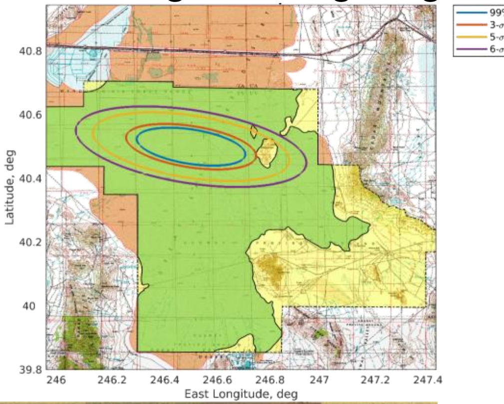
Ongoing and Future Work

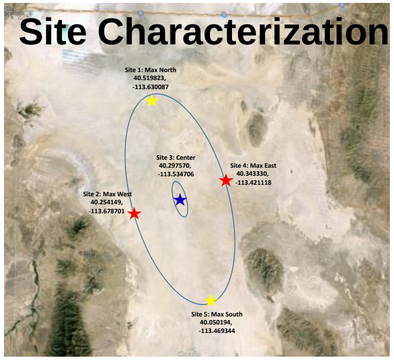
Preparations for a potential 2026 MSR EEV continue in many technical areas:

- Systems Engineering
- Delivery Trajectory
- Release and Space Flight
- MMOD Risk
- Atmospheric Entry
- Decent Aerodynamics
- Site Characterization
- Landing Site Targeting
- Impact Landing
- System Analysis Tools
- Advanced Modeling
- Flight certification

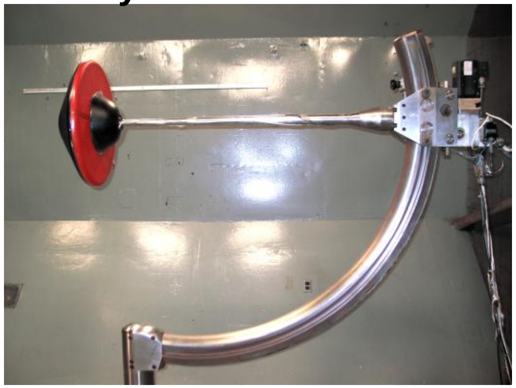


Landing Site Targeting

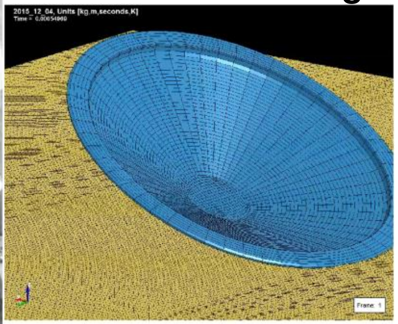




Aerodynamics



Advanced Modeling



THANK YOU FOR LISTENING!

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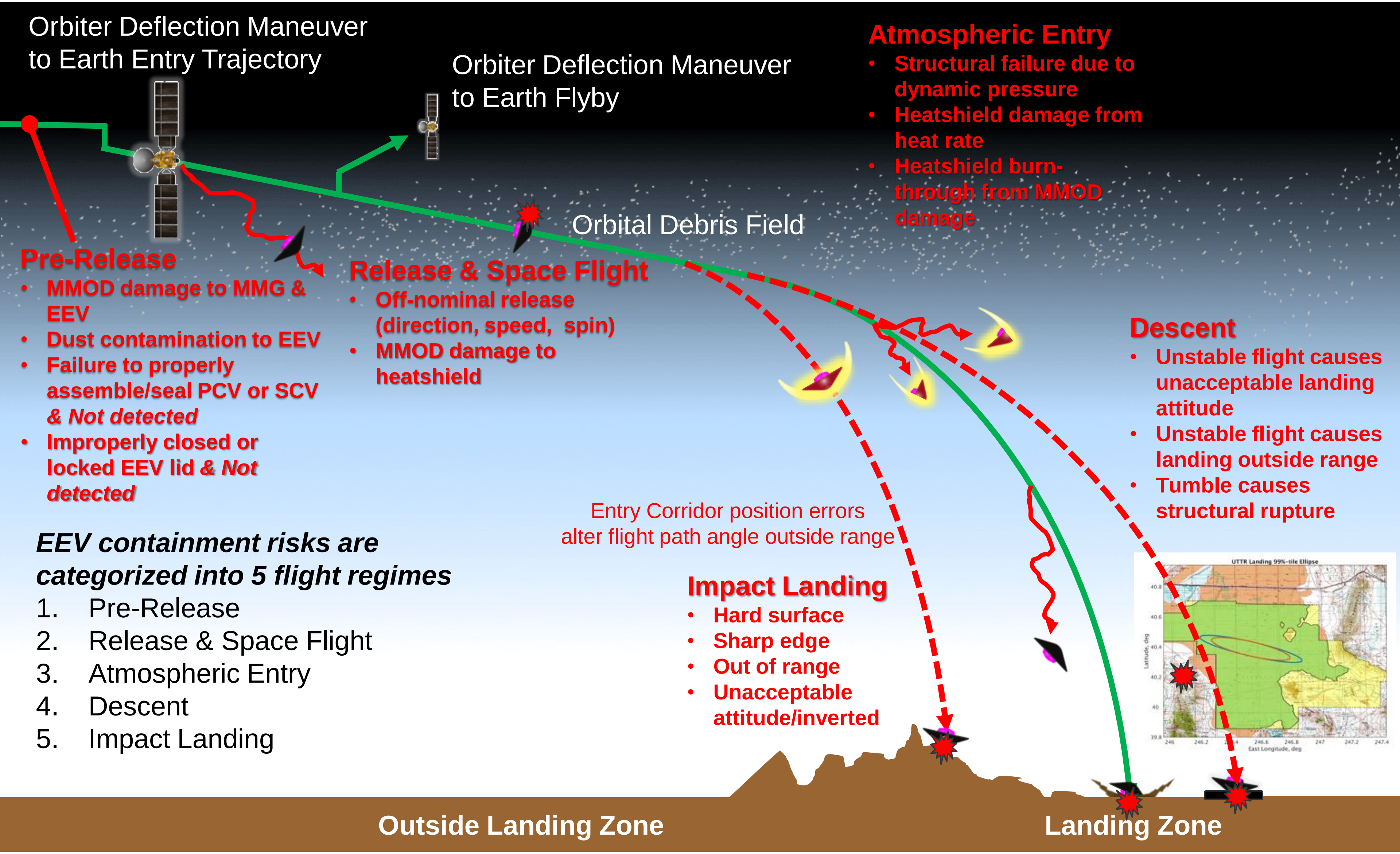
Backup

Key Risk Considerations



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